Manipulating Pretesting Conditions for Measuring Body Composition Using the BodPod and Bioelectrical Impedance

AN HONORS THESIS (HONR 499)

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Abstract

Body composition is defined as the proportion of fat mass to total body mass, represented as percent body fat. It is very important in health and physical fitness related settings to obtain accurate body composition measurements in order to accurately assess the health level of individuals. In this study a group of 20-23 year old females voluntarily participated in a study conducted in the Integrative Exercise Physiology Lab. In this study the BodPod and bioelectric impedance methods of body composition measurement were used on these subjects while 3 different pretesting conditions were manipulated. These conditions included food and drink consumption and exercise prior to the tests. The purpose of this study was to determine to what extent these pretesting conditions would affect the results and accuracy of both the BodPod and the bioelectric impedance.

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Introduction

Obesity refers to the condition of having an excessive amount of body fat. The prevalence of obesity in the United States has significantly increased in the last 50 years. It has increased from approximately 13% to 33% of age-adjusted population from 1960 to 2007, respectively. Obesity is associated with an increased overall rate of death. The most common diseases that exist comorbid with obesity are coronary heart disease, hypertension, stroke, type 2 diabetes, cancer (endometrial, breast, and colon), liver and gall bladder disease, osteoarthritis, sleep apnea and respiratory problems (5). Body composition describes the relative proportions of fat, bone, and muscle mass in the human body. Health professionals use body composition to gain important information about percent body fat, fat distribution, body segment girth, and lean tissue mass (7). Body composition plays a huge role in assessing the presence of obesity and overall health; this is why accurate measurement of body composition is so crucial.

There are many different ways to assess body composition. The most commonly used methods include: body mass index (BMI), skinfold measurement, hydrostatic weighing (HW), dual-energy X-ray absorptiometry (DEXA), air plethysmography (BodPod), and bioelectric impedance (BIA). Anthropometry involves the measurement of the human body using simple physical techniques. Height, and weight are measured to determine body mass index (body mass/ height squared; kg m^2). This method is used to predict the risk of developing type 2 diabetes, hypertension, and other cardiovascular diseases. While this method is very easy and quick to use, it is not a reliable predictor of disease, especially in athletes and highly active individuals.

Another popular method of predicting percent fat is skinfold measurement. Skinfold analysis is based on the idea that the amount of subcutaneous fat is directly proportional to the total amount of body fat. The number of sites needs to be predetermined based on the regression equation or methods used (three, four, or seven-site skinfold). Then, a fold of skin is firmly grasped between the thumb and index finger with the left hand (about 8 cm apart on a line perpendicular to the long axis of the site) and lifted away from the body while the subject relaxes. Palpation of the fold warrants that subcutaneous tissue (skin, fat) is measured and not the skeletal muscle. While the caliper dial is facing up, the jaws of the caliper are opened and placed over the skinfold 1 cm below the fingers of the tester directly at the designated anatomical site. Then the grip of the caliper is released, and the skinfold measurement is taken within 2-3 seconds while the tester's other hand keeps the grip of the skinfold. All measurements should be taken on the right side of the body. Each site is taken 2-3 times and then averaged. The sites are summed to estimate percent body fat using a regression equation or prediction table. While skinfold measurement is quick, easy, and cheap, its reliability and accuracy is often questioned. The accuracy can depend on the technician, the calipers, the skinfold regression equation used (SEE $\pm$3.5%) (7).

Hydrostatic weighing is considered the golden standard for assessing body composition because of its very high accuracy (SEE $\pm$2.5%). This method involves submersing the subject completely underwater. From there, the difference between the subject's scale weight and underwater weight (corrected for the density of water) equals the body's volume (2).

> "HW is based on Archimedes' principal for determining body density. Archimedes' principal states that a body immersed in water is subjected to a buoyant force that results in a loss of weight equal to the weight of the displaced water. Subtracting the body weight measured in the water during submersion from the body weight measured on land provides the weight of the displaced water. Body fat contributes to buoyancy because the assumed density of fat (0.9007 g x cm^{-3}) is less than water (1 g x cm^{-3}), whereas FFM (assumed to average 1.100 g x cm^{-3}) exceeds the density of water. Density is inversely related to body fat. Thus HW is based on the equation: body density = mass x $volume^{-1}$. "(7)

This method is very accurate when done correctly; however it does have negative aspects. Hydrostatic weighing is very expensive and poses many other limitations such as: the time taken for measurement, need for accurate residual volume measurement, and the discomfort of the participants being fully submerged underwater (5)

In addition, the dual energy X-ray absorptiometry (DEXA) is another method used to measure body composition/density. The DEXA method allows the quantification of bone and soft tissue composition (5). The principal of DEXA is based on exponential attenuation of X-rays at two energies as they pass through the body. X-rays are generated at two energies via a low-current X-ray tube under the DEXA machine. A detector is positioned above on the scanning arm and interface with a computer that is needed for scanning the image. The subject lays still on the table while the scanner passes over the body from head to toe. "The ratio of soft tissue attenuation of the low- and high-energy beams is measured as follows: soft tissue attenuation (low and high energy) = proportion of fat (fat attenuation) + proportion of lean tissue (attenuation of lean tissue) Thus, a 3C model is seen as soft tissue mass divided into FFM and fat mass" (7). It provides total body estimates that are very accurate and precise. An advantage that DEXA has that the other methods do not have is the ability to estimate bone density as well as fat-free mass (SEE $\pm$1.8). It is also more comfortable for the subject than hydrostatic weighing; however, the DEXA is very expensive and requires very precise and technical support (5).

In this study, body composition will be measured using air plethysmography (BodPod) and bioelectrical impedance (BIA). The BodPod is a technique that measures volume using air displacement. This method involves a closed chamber of room air at atmospheric pressure, which we have a known volume for. The subject then enters the chamber, sits still, and closes the airtight door. Using Boyle's law (P1 x V1= P2 x V2), the new volume of the air inside the chamber is then measured, which will then be subtracted from the original chamber volume, determining the volume of the subject's body (3). Once the subject's volume is found,
volume can be converted to density using the equation D=M/V which we can then use to estimate body fat. Two of the most common prediction equations used to estimate percent body fat from body density are derived from the two-component model of body composition:

% Fat= (457/Body Density) – 414.2

% Fat= (495/ Body Density) – 450

This is a simple technique; however it requires very high accuracy when controlling for temperatures, gas composition, and the subject's breathing inside the chamber. While the BodPod is very accurate (SEE is $\pm$ 2.2%- 3.7%), it is also very expensive and can cause the subject to feel claustrophobic inside such a small space (5).

The second method of body composition that will be used in this study includes the bioelectric impedance method. The premise underlying this method is that fat-free tissue in the body is proportional to the electrical conductivity in the body (7). In this method, the subjects lay supine on a flat surface with hands and legs at their side and not contacting any other part of the body. Then, four electrodes are attached to the body (at the ankle, foot, wrist, and back of hand). An unnoticeable current is then passed through the hand and foot electrodes. The wrist and ankle receive the current flow. Measurements of the impedance and/or conductivity are used to estimate relative body fat (4). According to ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription,

> "the theory underlying the bioelectrical impedance method is that lean tissue (mostly water and electrolytes) is a good electrical conductor and acts as impedance to electrical current. A single-frequency (50 kHz), low-level current (500 mA) is used to measure whole-body impedance using electrodes placed on two distant peripheral sites. Higher frequencies

penetrate the cell membranes and flow through both the intracellular and extracellular fluid. Total body impedance at the constant frequency 50 kHz reflects the volumes of intracellular and extracellular fluid and muscle compartments constituting the FFM. The equation most commonly used when studying BIA is: $V= pL^2 \times R^{1}$"

V= volume of conductor, p= specific resistance of tissue, L= length of conductor, R= observed resistance (7).

The relative body fat in athletic populations tends to be overestimated using the BIA method because of the equations used. Hydration also can alter the results in this method. This technique is fairly cheap and is popular because the subject isn't enclosed in an uncomfortable space. Because this method uses electrodes and seems to be a very technical device, subjects tend to favor this over some of the other methods. Additionally, less technician support is required (5).

It is very clear that body composition is extremely important in predicting and assessing obesity. Obesity is a deadly disease that can cause numerous health problems. While there are several methods of obtaining body composition measurements; it is significant to know which ones have the highest accuracy. It is valuable to not only know which methods are most accurate, but also how to perform the techniques in the most accurate manner. Violating pretesting instructions can alter the results obtained by the different methods of body composition measurement. Less accurate results may have an impact on the estimate of an individual's overall health and fitness.

The purpose of this study is to determine the extent to which the BodPod and BIA techniques can be skewed by violating 3 different pretesting conditions. It is hypothesized that prior food/drink consumption will alter the percent fat obtained using the BIA and 25 minutes of prior exercise will alter the percent fat obtained using the BodPod.

Methods

The population of this study consisted of a group of 4 healthy college age females between the ages of 20 and 23. On average, all participants engage in at least 30 minutes of moderate intensity 7 days a week. Moderate intensity activity is defined as 3.0-6.0 METS. According to the Compendium of Physical Activities Tracking Guide, moderate intensity exercise would include walking downstairs (3.0 METS), vacuuming (3.5 METS), leisure bike ride at 10-11.9 mph (6.0 METS), etc. (1). The Integrative Exercise Physiology lab's BodPod and bioelectrical impedance methods were used to measure each participant's body composition.

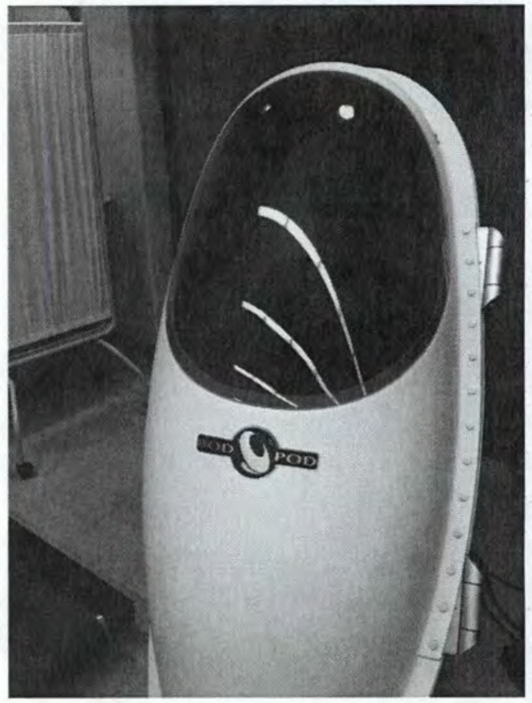
The three conditions that were manipulated were hydration status, prior exercise, and prior food consumption. Each pretesting condition was randomly manipulated for each trial. Prior to one visit, the subjects adhered to all bioelectrical impedance pre-test conditions. These pretest conditions included: no alcohol consumption for the previous 48 hours before the test, no products with diuretic properties (caffeine, chocolate, etc.) for the previous 24 hours before the test, no exercise for the previous 12 hours before the test, no eating or drinking for the previous 4 hours before the test, and bladder should be voided completely within 30 minutes of the test (5). These pretesting conditions were also used prior to using the

BodPod. All other manufacturing instructions were followed prior to using the BodPod. For a second trial, subjects adhered to all pretest conditions but freely ate and drank during the 4 hours before the test. For the third condition, subjects adhered to all pretest conditions but rode a cycle ergometer for 25 minutes prior to the test. Each participant also filled out a PAR-Q and informed consent prior to the test.

During the BodPod trials, the device was calibrated and each subject was weighed wearing proper clothing and no jewelry. Then, each subject entered the chamber, the door was closed, and then the test began. The BodPod collected the measurements and reported them back on the computer screen. If the results were inconsistent, the test was done again.

During the BIA trials, the device was calibrated according to each subject's age, gender, height, weight, activity level, and waist/hip circumference. Then, the subjects lay down on a flat surface and electrodes were correctly placed on the necessary locations on each subject. Data was collected a minimum of two times and then averaged together.

Pictured below: one subject using the BodPod while wearing the necessary clothing (tight-fitting clothes, swim cap, no jewelry)



Pictured below: Bioelectric impedance method: electrodes correctly placed on subject

The primary dependent variables were lean mass, percent fat, fat weight. The independent variable is the specific condition (control, prior food/drink, exercise).

The data were presented as means $\pm$ SD. Dependent variables across the trials will be analyzed by a one-way ANOVA. The significance if $p< 0.05$. This analysis was done using SPSS V.23 and the post-HOC pairwise comparisons were done using Fisher's LSD.

As a secondary analysis, the BIA was compared to the BodPod since the BodPod is supposed to be more accurate than the BIA. Paired sample t-tests were done on the percent fat values between the BodPod and BIA.

Results

Table 1 shows the anthropometric measurements obtained from 4 college-aged females. Table 2 shows the randomly generated pretest conditions that were followed for each trial. Each trial was done one week apart from one another at 6:00 PM.

BIA was not significantly different among the three trials. Table 3 shows the means and standard deviations among the 3 pretesting conditions.

The BodPod was not affected by eating/drinking, but the percent fat values during the exercise trials were significantly lower than the other two trials ($p < 0.05$). Table 4 represents these significant differences. The two most important variables examined were percent fat and lean mass.

Table 1. Physical Characteristic of Sample Population

Subject	Age	Height	Weight	BMI
1	20	157 cm	53.2 kg	21.65
2	23	165 cm	60 kg	21.78

3	22	170 cm	60.4 kg	21.98
4	22	168 cm	66.8 kg	24.03

Table 2. Randomly Generated Pretesting Conditions

Subject	Trial 1	Trial 2	Trial 3
1	Control	Eat/drink	Exercise
2	Exercise	Eat/drink	Control
3	Eat/drink	Exercise	Control
4	Eat/drink	Control	Exercise

Table 3. BIA Means and Standard Deviations for 3 Conditions

	Mean	SD+/-
BIA Control % fat	26.4500	1.8005
BIA Control lean weight (kg)	44.4875	5.2495
BIA Control Dry Lean (kg)	13.9500	2.0392
BIA Control % water	50.5250	1.2926
BIA Exercise % fat	25.300	1.0231
BIA Exercise lean weight (kg)	45.225	4.1161
BIA Exercise Dry Lean (kg)	13.800	1.8493
BIA Exercise % water	51.975	1.3937
BIA Food/Drink % fat	24.2750	2.1934
BIA Food/Drink lean weight (kg)	45.8250	2.97447
BIA Food/Drink Dry lean (kg)	14.0375	1.48064
BIA Food/Drink % water	52.4875	2.27683

Table 4. BodPod Means and Standard Deviations for 3 Conditions

	Mean	SD +/-
BodPod Control % fat	24.775	2.8837
BodPod Control lean weight (kg)	45.975	10.702
BodPod Exercise % fat	21.025*	3.9752
BodPod Exercise lean weight (kg)	47.585*	4.3646
BodPod Food/Drink % fat	24.875	3.5453
BodPod Food/Drink lean weight (kg)	45.660	4.5427

Significant differences are indicated with a * to represent when the p-value <0.05

Discussion

The purpose of this study was to determine to what extent the independent variable affected the accuracy of both the BodPod and bioelectrical impedance methods of body composition measurement. After analyzing the results it was found that the BIA was notably consistent when exercise and food/drink was manipulated. Because of the BIA's less accurate reputation, it was originally expected to be more easily affected by things like food/drink consumption; however, the influence of eating/drink/exercising may not have substantially altered total body water. This suggests that the BIA would be an appropriate method of testing body composition in a health and fitness-related setting where pre-testing conditions may not be extremely well controlled.

After analyzing results it was also found that exercise significantly affected the percent fat and lean mass values obtained by the BodPod. There are many different sources of error that can happen when using a BodPod. These sources of error include: interlaboratory variation, variations in testing conditions, performing testing while not in a fasting state, air that is not accounted for in the lungs or trapped within clothing/hair, and body moisture, and most importantly increased body temperature (7). Since the BodPod uses air displacement plethysmography, body temperature is an essential variable that must be controlled. When subjects exercise, their body temperature increases significantly. According to the American Journal of Clinical Nutrition, "when a constant temperature is maintained (isothermal conditions), Boyle's Law can be applied. Consequently, most early plethysmographs required temperature-controlling surroundings and isothermal conditions within the test chamber." As temperature increases, gas molecules expand and become less dense, which means that the pressure increases. Pressure is an extremely important variable when using the BodPod. Measurement of volume using this method depends on Boyle's Law, through which pressure and volume are inversely related at a constant temperature (2). The American Journal of Clinical Nutrition did 2 studies that assessed the effect of body temperature on the percent fat measurements taken by the BodPod. In these studies they manipulated whether or not they used Hydrostatic Weighing prior to or after using the BodPod. "If subjects are recovering from situations that elevate metabolism (e.g., exercise, or presence in a tank of warm water for 10-15 min as part of the HW procedure), breathing patterns are likely to change over time... When the BodPod tests were conducted 10-15 min after HW, body fat was 2.3% lower than it was when measured before HW " (3). These findings can be related to this study because the body fat percentages obtained with the BodPod were also significantly lower when recovering from exercise. Inversely, the lean weights obtained using the BodPod were higher when the pretest conditions involved exercise. Since there was a decreased body fat percentage, this would mean that there would be more lean weight.

The hypothesis that prior food/drink consumption would alter the percent fat using the BIA was not proven correct; however, the hypothesis that 25 minutes of prior exercise would alter the percent fat obtained using the BodPod was indeed correct. There are plenty of limitations to the study that was conducted. Since the trials were done one-week apart from one another, the subject's body weight fluctuated week-to-week. If this same study was conducted again, it would be beneficial to conduct it in the same one-week period to avoid these fluctuations. Also, it would be important to control for menstrual cycle phase in order to eliminate the potential hormonal impact on variables under examination. In addition, since each subject was not observed for the entire 3-week period, there was no way to know if the subjects truly abided by all of the pretesting conditions. If the study was conducted again, it would be valuable to test a larger population with a larger standard deviation of weight, height etc. It would be interesting to see if exercise affects subjects with higher/lower activity levels and body types. Different methods of body composition measurement like hydrostatic weighing and DEXA could be used to see how these same pretesting conditions affect these methods as well.

In conclusion, results of this study indicate the BIA technique consistently and accurately estimates body composition even when all three pretesting conditions are manipulated. The BodPod also reported consistent results when food/drink was manipulated; however, when exercise was manipulated significant differences were observed in percent body fat and lean mass. Though it is recommended that subjects follow all necessary pretesting instructions prior to body composition assessment, it appears that violating the guidelines regarding eating and drinking does not adversely affect results of the test. Exercising immediately prior to assessment may invalidate BodPod results, but does not influence estimations generated by BIA. Results of this study may be useful for professionals who measure body composition in a clinical or health and fitness setting.

References

(1) Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, Greer JL, Vezina J, Whitt- Glover MC, Leon AS. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine and Science in Sports and Exercise*, 2011;43(8):1575-1581.

(2) Cornier, M., Despres, J., & Davis, N. et al. (2011, September 26). Assessing Adiposity: A Scientific Statement From the American Heart Association. Retrieved April 26, 2016, from http://circ.ahajournals.org/content/124/18/1996.full.pdf html

(3) Fields, D. A., McCrory, M. I., & McCrory, M. A. (2002, March). Body-Composition Assessment via Air-Displacement Plethysmography in Adults and Children: A Review 1'2'3'. Retrieved April 25, 2016, from http://ajcn.nutrition.org/content/75/3/453.full

(4) Kaminsky, L. A. (2010). *ACSM's health-related physical fitness assessment manual* (4th ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins Health.

(5) Kenney, W. L., Wilmore, J. H., & Costill, D. L. (n.d.). *Physiology of Sport and Exercise* (5th ed.).

(6) Pescatello, L., Ross, A., & Riebe, D. (2014). *ACSM's Guidelines for exercise testing and prescription: American College of Sports Medicine* (9th ed.). Philadelphia: Lippincott Williams and Wilkins.

(7) Swain, D. P. (2014). *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia; Baltimore; New York; London; Buenos Aires; Hong Kong; Sydney; Tokyo: Wolters Kluwer Health/Lippincott Williams & Wilkins.